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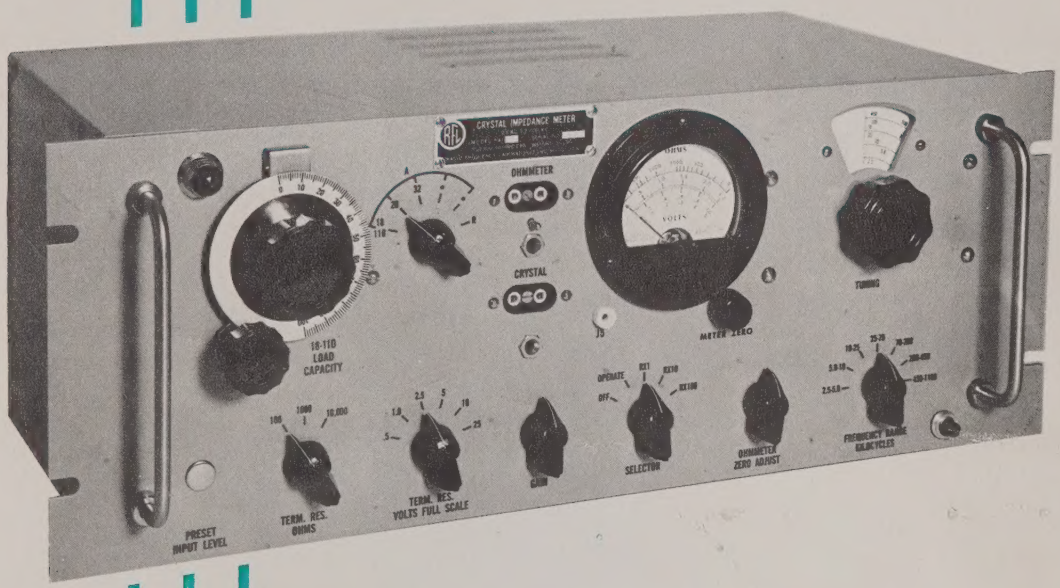
Model 541C

INSTRUCTION MANUAL



2.5-1100kc
CRYSTAL IMPEDANCE METER
(TS-710/TSM Improved Type)

RFL Industries, Inc.
Boonton, New Jersey, U.S.A.

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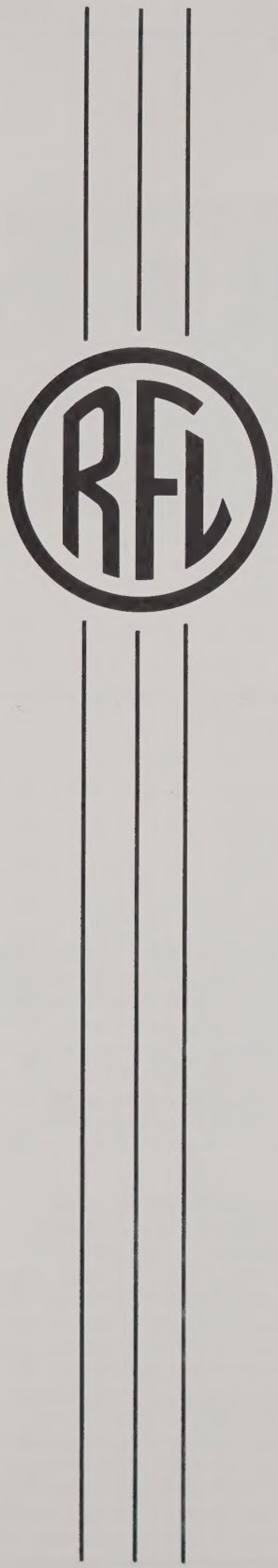

MANUAL OF
INSTRUCTIONS

Model 541C

2.5-1100kc
CRYSTAL IMPEDANCE METER
(TS-710/TSM Improved Type)

Book No. MA-23300A

RFL Industries, Inc.

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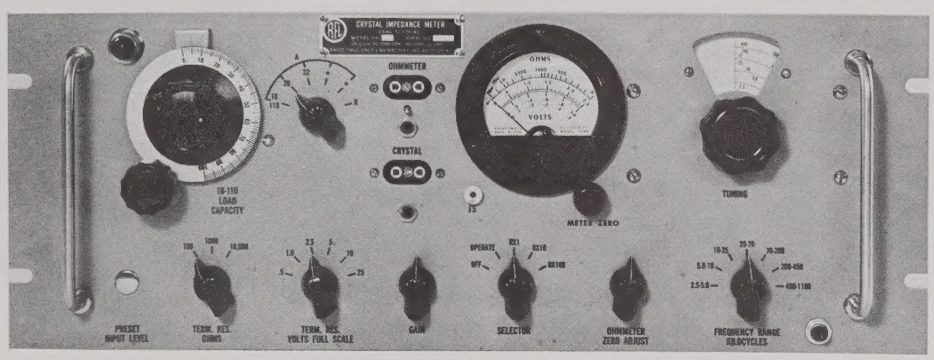


Figure 1. Front Panel of the Model 541C.

DESCRIPTION

GENERAL

The Model 541C Crystal Impedance Meter is designed to measure directly the effective resonance and anti-resonance resistance of quartz crystal units in the frequency range of 2.5-1100 kHz. The Model 541C is used as a Gov't. reference standard or as a crystal supplier's equivalent test set under paragraph 4.1.1.1.1 of U.S. Spec. MIL-C-3098C and U.K. Defence Spec. DEF-5271-A. Performance and operational characteristics of the Model 541C are identical to the TS-710/TSM.

The Model 541C is equivalent in all respects to the original Signal Corps Crystal Impedance Meter TS-710/TSM with the modifications as described at the 19th Annual Symposium on Frequency Control (1965) at Atlantic City, N.J. and in Technical Report ECOM-2618, "Modification of Test Set, Crystal Unit Quartz TS-710/TSM" by C.L. Shibla. These modifications consist of a change in the AC voltmeter circuit to read the voltage across shunts to measure crystal current for setting drive levels and redesign of the automatic gain control circuit to limit power into the crystal in GO-NO-GO operation. As with the TS-710/TSM, care must still be exercised not to exceed the rated crystal drive level. This is best accomplished in GO-NO-GO operation by measuring a group of crystals and determining an average crystal impedance to base the rated drive level upon. Nominal drive level of military crystals is set with a substitution resistor equal to 70% of the maximum specified resistor. The Model 541C has improved frequency accuracy over the TS-710/TSM by the addition of fixed load capacitors of 20 and 32 pf (±0.1 pf). Two additional tuning coils have been added to the range switch to permit the testing of crystals in the 2.5KC to 10KC frequency range. Large values of coupling capacitors have been used to allow operation on the lowest range (down to 800 Hz) by the use of an external decade capacitor box for tuning.

A built-in vacuum tube voltmeter measures the current of the crystal network by shunt resistor and enables the operator to set the power dissipated in the crystal unit. For convenience in measuring the resistance of the variable resistance adapters during the test procedure, an ohmmeter is also included. Also supplied are a 5-foot output cable with plug attached, fourteen fixed calibrating resistors, and three variable resistance adapters. The three variable resistors have maximum resistance values of 5K, 50K and 500K. Two socket adapters are furnished that allow the testing of crystal units contained in HC-5/U and octal base holders. All the fixed resistors and adapters are contained in a small metal box approximately $7\frac{1}{2}$ x 5 x 2 inches. The C.I. meter is housed in a grey, smooth-finished metal case designed for rack mounting. The overall dimensions are 19" long by $10\frac{1}{2}$" wide by 7" high.

The unit operates from a single phase power source of 115 or 230 volts AC, 50 to 1000 Hz.

DESCRIPTION OF MINOR COMPONENTS

a. Fourteen plastic encased calibrating resistors, with pin connections to match the spacing of the crystal socket and having fixed values 3K, 4K, 5K, 6K, 7K, 8K, 10K, 20K, 50K, 75K, 100K, 125K, 150K, 200K ohms are supplied. These resistors are within ±1% of the nominal value.

b. Three variable calibrating resistor assemblies are also supplied. These contain composition rheostats with maximum values of 5K, 50K, and 500K ohms and have pin connectors so that they may be plugged into the CRYSTAL or OHMMETER sockets which also accommodate HC-6/U and HC-13/U holders.

c. Two adapters are supplied. One allows the use of crystal units in HC-5/U and HC-21/U holders to be plugged into the CRYSTAL socket. The other adapter performs the same function for crystal units mounted in octal base holders.

d. A 5-foot r-f output cable assembly is also supplied. The cable has a UG-88/U connector on one end, the other end has no termination.

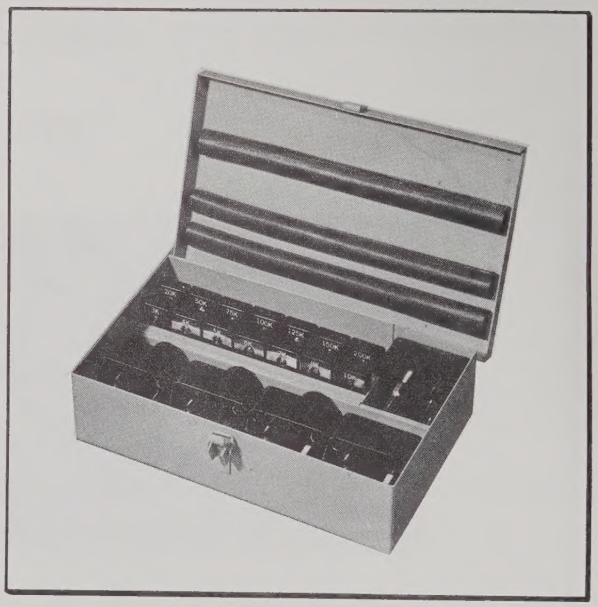


Figure 2. Calibrating Resistors and Adapters.

Table I. Technical Characteristics

FREQUENCY RANGES (7)

2.5-5.0, 5-10, 10-25, 25-70, 70-200, 200-450 and 450-1100 kHz.
(down to 800 Hz using external capacitors)

CRYSTAL IMPEDANCE RANGE

200 ohms to 0.5 megohm

PANEL VOLTMETER RANGE

0.5 to 25 volts full scale

CRYSTAL CURRENT SHUNTS

100; 1000; 10,000 ohms

LOAD CAPACITANCE

20 and 32 pf precise fixed load capacitors, accurate to ±0.1 pf. Also 18 to 110 pf variable capacitor with dial. Calibration chart supplied accurate to ±1 pf.

OHMMETER RANGE

100 ohms to 1 megohm with ±10% accuracy.

RESISTANCE CALIBRATION

Fourteen calibrating resistors with values of 3K, 4K, 5K, 6K, 7K, 8K, 10K, 20K, 50K, 75K, 100K, 125K, 150K and 200K. Three variable resistance adapters with maximum resistance values of 5K, 50K, and 500K.

TUBE COMPLEMENT (7)

Drive amplifier	V1 6005
Phase-inverter-amplifier	V2 5749
Voltmeter	V3 5751
Rectifier	V4 5Y3W
Voltage regulator	V5 OB2
Voltage regulator	V6 OA2
Voltmeter rectifier	V7 5726

REQUIRED POWER SOURCE

115 or 230 volts AC, 50 to 1000 Hz, 80 watts.

Table 2. Controls and their Functions

CONTROL	FUNCTION
LOAD CAPACITY	Calibrated dial varies load capacitor from 18 to 110 pf.
A-R	Switch across load capacitor. In the A positions the capacitor is in series with the crystal socket and in the R position the capacitor is shorted out of the circuit. Selects fixed capacitors of 20 and 32 pf, the variable capacitor, and two positions for external capacitors which can be selected according to use.
PRESET INPUT LEVEL	A recessed potentiometer allowing the setting of input levels to the crystal network.
GAIN	Varies the loop gain of the oscillator circuit.
SELECTOR	Contains the AC power switch and circuits to energize either the oscillator or ohmmeter circuits.
OHMMETER ZERO ADJUST	Sets the ohmmeter zero on each of the three resistance ranges.
FREQUENCY RANGE KILOCYCLES	Band switch selects correct coil for frequency range.
TUNING	Varies tuning capacitor to cover frequency range.
TERM. RES. OHMS	Sets values of shunt resistor to measure crystal current.
TERM. RES. VOLTS FULL SCALE	Sets range of voltmeter to measure crystal current.
JACKS J3, J4 (on rear of chassis)	Allows the connection of a .001 to .01 decade capacitor box across the 4-henry tuning coil on the 2.5 to 5.0 kHz range for operation down to 800 Hz.

There is one other switch on the front panel. It is located just below the OHMMETER socket. In its normal position it is closed and places a short across the OHMMETER socket. This facilitates the zero adjustment on the three ohmmeter ranges. When an adapter is inserted into the socket, it pushes the button in and opens the switch. The ohmmeter then reads the resistance of the adapter.

INSTALLATION & ADJUSTMENT

INSTALLATION OF EQUIPMENT

The following steps should be followed in the installation of the equipment:

a. Thoroughly inspect the exterior of the Crystal Impedance Meter for possible damage in shipment.

b. Loosen the nine binding head screws on the sides and back of the unit and remove the metal dust cover. Also remove the bottom cover plate.

c. Make sure no vacuum tubes are broken and that they are properly seated in their sockets.

d. Inspect the wiring to make certain that the leads are securely fastened to points of contact.

e. Inspect the subassembly parts, such as terminal strips, to make certain they are securely fastened in place.

f. Replace the dust cover and bottom cover plate.

CONTROLS

Haphazard operation or improper setting of the controls can cause damage to electronic equipment. For this reason it is important to know the function of every control. The actual operation of the equipment is discussed below under Operation.

CAUTION

It is of great importance that the line "Voltage Change-over" switch S6 on the rear of the unit be correctly set and locked in the operating position.

INITIAL ADJUSTMENT

All initial adjustments of the Model 541C are made at the factory and field adjustments should be unnecessary.

OPERATION

STARTING PROCEDURE

a. Set TERM. RES. VOLTS FULL SCALE to 0.5 volt.

b. Set GAIN control fully counterclockwise.

c. Set SELECTOR switch to OFF.

d. Determine whether the power source is 115 or 230 volts, and lock the Voltage Change-over switch (located on back of chassis) in the proper position.

e. Insert the power cord into the AC outlet.

OPERATING PROCEDURE

The crystal frequency and drive level as specified by the crystal manufacturer must be known before it can be tested.

MEASUREMENT OF RESONANCE RESISTANCE

(1) Set the SELECTOR switch to OPERATE and allow 15 minutes for the Crystal Impedance Meter to warm up.

(2) Set the FREQUENCY RANGE switch to the desired range and rotate the TUNING knob to set the meter to the frequency of the crystal unit. Note that the markings on the tuning dial are only approximate frequency values, they are not for precise frequency measurement.

(3) Rotate the A-R switch to R.

(4) Rotate TERM. RES. VOLTS control to 0.5 volt and TERM. RES. OHMS to 1000 ohms for 2 m.w. crystals and 10,000 ohms for 0.1 m.w. crystals. (Crystal types CR-39/U and CR-40/U are tested with a terminating resistor of 100 ohms and an external voltmeter plugged into front panel jack J5.)

(5) Insert the crystal unit into the CRYSTAL socket.

CAUTION

Some crystal units tested in this unit may begin to oscillate very slowly and then build up quickly. Therefore, it is necessary to advance the gain control slowly during this procedure. At times it is also necessary, as soon as the crystal unit starts to oscillate, to rotate the gain control counterclockwise (reducing the driving voltage) to keep the crystal unit from shattering. Do not exceed the drive level as specified by the crystal manufacturer.

(6) Slowly advance the GAIN control while rocking the TUNING knob back and forth through the frequency of the crystal unit.

(7) When an adequate meter indication is obtained, adjust the TUNING knob for maximum meter indication. Adjust the meter to approximately half-scale with the GAIN control.

(8) Connect the RF cable from output jack J1 (on the back of the chassis) to a suitable frequency measuring device. An electronic frequency counter is most convenient. Obtain an approximate measurement of the crystal frequency.

(9) Replace the crystal unit with the 50K variable resistance adapter (set at maximum resistance, counterclockwise) and adjust the adapter for the same voltmeter indication that was obtained with the crystal unit. If the 50K adapter is of too low a resistance (meter goes off-scale), use the 500K adapter, starting at the maximum resistance. Retune the Model 541C for zero beat or the same output frequency that was obtained with the crystal unit.

(10) Remove the calibrating resistor and replace with the crystal unit. Use the GAIN control to adjust the voltmeter to a convenient reading and retune the frequency measuring equipment for zero beat.

(11) Repeat steps (9) and (10) until the meter readings and output frequencies are the same for both the crystal unit and the calibrating resistor.

(12) In order to measure the resistance of the calibrating resistor (which is now equal to the effective crystal resonance resistance), rotate the SELECTOR switch to the R x 1 position and rotate the OHMMETER ZERO ADJUST control until the meter reads zero ohms. Insert the calibrating resistor firmly into the OHMMETER socket. If a small meter indication is obtained, pull the resistor out about 1/4-inch or until the meter reads zero, and advance the SELECTOR switch to the R x 10 or R x 100 position and zero meter if necessary. Again push the resistor firmly into the socket to obtain the ohmmeter reading.

(13) In order to find the power dissipated in the crystal unit, use the following formulae:

$$P = I^2 R \text{ or } P = \left(\frac{E}{R_s}\right)^2 R$$

where:

P = Drive power in watts.
E = Voltmeter reading in volts across Rs.
I = Current through crystal.
R = Effective crystal resonance resistance in ohms.
Rs = Term. Res. in ohms.

(14) An accurate measurement of the crystal unit's operating frequency now can be made. Plug the crystal unit into the CRYSTAL socket and rotate the SELECTOR switch to the OPERATE position.

(15) Set the drive level with the front panel voltmeter as calculated in paragraph (13) or by use of the curves of figures 5 and 6 and appropriate voltmeter range.

(16) Measure the frequency of the crystal unit.

Then repeat the above operating procedure from paragraphs (1) to (16) with the proper drive setting until resistance values repeat.

MEASUREMENT OF
ANTI-RESONANCE RESISTANCE

(1) Set the SELECTOR switch to OPERATE and allow 15 minutes for the Model 541C to warm up.

(2) Set the FREQUENCY RANGE switch to the desired range and rotate the TUNING knob to the approximate frequency of the crystal unit. Note that the markings on the tuning dial are only approximate frequency values; they are not for precise frequency measurements.

(3) Rotate the A-R switch to desired A position.

(4) Adjust the LOAD CAPACITY dial to the proper setting or set A-R switch to fixed value desired. Calibration data for dial are given in the calibration chart supplied with the equipment.

(5) Rotate TERM. RES. VOLTS control to 0.5 volt and TERM. RES. OHMS to 1000 ohms for 2 m.w. crystals and 10,000 ohms for 0.1 m.w. crystals. (Crystal types CR-39/U and CR-40/U are tested with a terminating resistor of 100 ohms and an external voltmeter plugged into front panel jack J5.)

CAUTION

Some crystal units tested in this unit may begin to oscillate very slowly and then build up quickly. Therefore, it is necessary to advance the gain control slowly during this procedure. At times it is also necessary, as soon as the crystal unit starts to oscillate, to rotate the gain control counterclockwise (reducing the driving voltage) to keep the crystal unit from shattering.

(6) Insert the crystal unit into the CRYSTAL socket.

(7) Slowly advance the GAIN control while rocking the TUNING knob back and forth through the frequency of the crystal unit.

(8) When an adequate meter indication is obtained, adjust the TUNING knob for a maximum meter indication. Adjust the meter to approximately half-scale with the GAIN control.

(9) Connect the RF cable from output jack J1 (on the back of the chassis) to a suitable frequency measuring device. Obtain an approximate measurement of the crystal frequency.

(10) Remove the crystal unit and rotate the A-R switch to the R position.

(11) Insert the 50K variable resistance adapter in the CRYSTAL socket (set at maximum resistance) and adjust the adapter for the same voltmeter indication that was obtained with the crystal unit. If the 50K adapter is of too low a resistance (meter goes off-scale), use the 500K adapter starting at maximum resistance. Retune the Model 541C for zero beat or the same output frequency that was obtained with the crystal unit.

(12) Set the A-R switch to A position desired.

(13) Remove the calibrating resistor and replace with the crystal unit. Use the GAIN control to adjust the voltmeter to a convenient reading and retune the frequency measuring equipment for zero beat.

(14) Repeat steps (10) through (13) until the meter readings and output frequencies are the same for both the crystal unit and the calibrating resistor.

(15) In order to measure the resistance of the calibrating resistor (which is now equal to the effective anti-resonance resistance of the crystal unit), rotate the SELECTOR switch to the R x 1 position and rotate the OHMMETER ZERO ADJUST control until the meter reads zero. Insert the calibrating resistor firmly into the OHMMETER socket. If a small meter indication is obtained, pull the calibrating resistor out about one-quarter inch, or until the meter reads zero. Advance the SELECTOR switch to the R x 10 or R x 100 position and zero meter if necessary. Again push the resistor firmly into the socket to obtain the ohmmeter reading.

(16) In order to find the power dissipated in the crystal unit, use the following formulae:

$$P = I^2 R \text{ or } P = \left(\frac{E}{Rs}\right)^2 R$$

where:

P = Power in watts,
E = Voltmeter reading in volts across Rs.
I = Current through crystal.
R = Effective crystal anti-resonance in ohms.
Rs = Term. Res. in ohms.

(17) An accurate measurement of the crystal unit's operating frequency (at anti-resonance) now can be made. Plug the crystal unit into the CRYSTAL socket, rotate the A-R switch to A position and the SELECTOR switch to the OPERATE position. The frequency of the crystal unit at the calculated drive level may now be measured.

(18) If the operating frequency or anti-resonance resistance is to be determined at some other drive level, calculate the voltage drop across the shunt by paragraph (17) or use figures 5 and 6 to obtain the required voltmeter reading.

Then repeat the above operating procedure from paragraphs (1) to (15) and (17), except that in paragraphs (8) and (13) set the drive voltage at the proper value and continue with the remainder of the procedure. If wide variations are found in the resistance of the crystal unit, a more accurate measurement may be made by repeating the above procedure one more time so that the resistance values repeat.

PROCEDURE FOR USING THE MODEL 541C AS A GO, NO-GO GAGE IN RESONANCE OPERATION

CAUTION

GO, NO-GO tests should be performed at the lowest drive level recommended by the crystal manufacturer due to the possibility of shattering some types of crystal with high drive levels. See figure 3 for typical power vs resistance curves.

(1) Set the SELECTOR switch to OPERATE and allow 15 minutes for the equipment to warm up.

(2) Set the FREQUENCY RANGE switch to the desired range and rotate the TUNING knob to the approximate frequency of the crystal unit.

(3) Rotate the A-R switch to R.

(4) Rotate TERM. RES. VOLTS control to 0.5 volt and TERM. RES. OHMS to 1000 ohms for 2 m.w. crystals and 10,000 ohms for 0.1 m.w. crystals. (Crystal types CR-39/U and CR-40/U are tested with a terminating resistor of 100 ohms and an external voltmeter plugged into front panel jack J5.)

(5) Insert the crystal unit into the CRYSTAL socket.

(6) Slowly advance the GAIN control while rocking the tuning knob back and forth through the frequency of the crystal unit.

(7) When an adequate meter indication is obtained, adjust the TUNING knob for a maximum meter indication. Adjust the meter to approximately half-scale with the GAIN control.

(8) Connect the RF cable from output jack J1 (on the back of the chassis) to a suitable frequency measuring device. Obtain an approximate measurement of the crystal frequency.

(9) Remove the crystal unit and substitute a fixed calibrating resistor with a value of resistance that corresponds to 70% of the maximum resistance of the crystal unit under test.

(10) Determine the drive level setting from the drive level from calculations of paragraph (16), page 7 or by use of figures 5 and 6.

(11) Adjust the GAIN control so that the voltmeter reads the desired voltage. Note the reading of the voltmeter.

(12) Rotate the TUNING knob so that the signal is at or near zero beat with the frequency measured in paragraph (8).

(13) If necessary, readjust the GAIN control to obtain the voltage noted in step (11). This voltage is the passing activity level.

(14) Remove the calibrating resistor and insert resistor of value comparable to lowest expected crystal resistance. Check that maximum rated drive levels are not exceeded, or operation above rated drive can cause frequency shifts and or destruction of a crystal.

(15) Crystal units exhibiting a greater voltmeter reading than that set in paragraph (13) pass the activity requirements; those giving a smaller voltmeter reading fail. Check that crystals of lowest resistance are not over driven before beginning operation. Crystals that fail should be rechecked by substitution methods.

PROCEDURE FOR USING THE MODEL 541C AS A GO, NO-GO GAGE IN ANTI-RESONANCE OPERATION

CAUTION

GO, NO-GO tests should be performed at the lowest drive level recommended by the crystal manufacturer due to the possibility of shattering some types of crystal with high drive levels.

(1) Set the SELECTOR switch to OPERATE and allow 15 minutes for the equipment to warm up.

(2) Set the FREQUENCY RANGE switch to the desired range and rotate the TUNING knob to the approximate frequency of the crystal unit.

(3) Rotate the A-R switch to desired A position.

(4) Adjust the LOAD CAPACITY dial to the proper setting or set A-R switch to desired fixed value. Calibration data are given in the calibration chart supplied with the equipment.

(5) Rotate TERM. RES. VOLTS control to 0.5 volt and TERM. RES. OHMS to 1000 ohms for 2 m.w. crystals and 10,000 ohms for 0.1 m.w. crystals. (Crystal types CR-39/U and CR-40/U are tested with a terminating resistor of 100 ohms and an external voltmeter plugged into front panel jack J5.)

(6) Insert the crystal unit into the CRYSTAL socket.

(7) Slowly advance the GAIN control while rocking the TUNING knob back and forth through the frequency of the crystal unit.

(8) When an adequate meter indication is obtained adjust the TUNING knob for a maximum meter indication. Adjust the meter to approximately half-scale with the GAIN control.

(9) Connect the RF cable from output jack J1 (on the back of the chassis) to a suitable frequency measuring device. Obtain an approximate measurement of the crystal frequency.

(10) Remove the crystal unit and rotate the A-R switch to the R position.

(11) Insert in the CRYSTAL socket a fixed calibrating resistor with a value of resistance that corresponds to 70% of the maximum resistance of the crystal unit under test.

(12) Determine the drive level setting from the drive level from calculations of paragraph (16) page 7 or by use of figures 5 and 6.

(13) Adjust the GAIN control so that the voltmeter reads the desired voltage. Note the reading of the panel voltmeter.

(14) Rotate the TUNING knob so that the signal is at or near zero beat with the frequency measured in paragraph (9).

(15) If necessary, readjust the GAIN control to obtain the voltage noted in step (14). This voltage is the passing activity level.

(16) Change resistor to lowest expected crystal resistance and check that maximum drive levels are not exceeded. If so reduce drive level and repeat steps (13) to (15).

(17) Rotate the TUNING knob so that the signal is at or near zero beat with the frequency measured in paragraph (9).

(18) Remove the calibrating resistor and rotate the A-R switch to A position.

(19) Crystal units exhibiting a greater voltmeter reading than that obtained in paragraph (15) pass the activity requirements; those giving a smaller voltmeter reading fail. Check that crystals of lowest resistance are not overdriven before beginning operation.

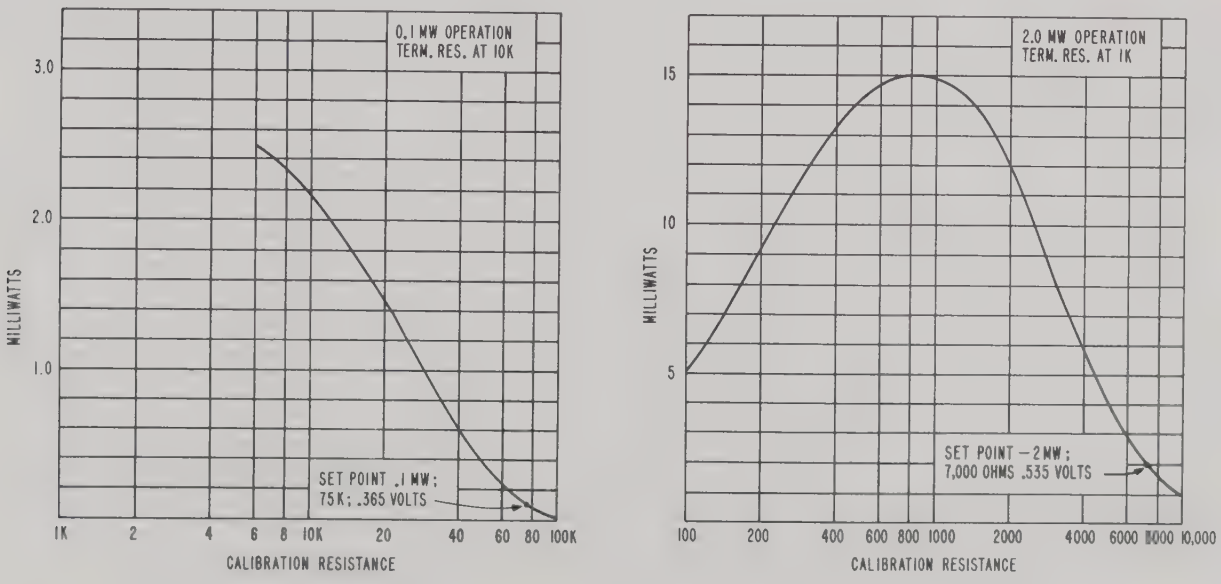


Figure 3. Typical Power vs Resistance Curves.

THEORY OF OPERATION

CRYSTAL PARAMETERS

PIEZOELECTRIC EFFECT

When an electrical stress is applied to a cut quartz crystal in the direction of one of the major axes, a mechanical stress is produced at right angles to this axis. Conversely, a mechanical stress along a major axis will cause electrical charges to appear on the faces of the crystal perpendicular to the stress axis. The polarity of the electrical stress and the direction of the corresponding mechanical force are interrelated; a reversal in one causes a reversal in the other. This relationship between electrical stress and mechanical force is termed the piezoelectric effect and provides a means of relating mechanical vibrations to electrical circuits.

RESONANCE

An alternating voltage applied across a quartz crystal will cause the crystal to vibrate. If the frequency of the applied alternating voltage approximates a frequency at which mechanical resonance can exist in the crystal, the amplitude of the vibrations will be very large. Any crystal has several such resonant frequencies that depend on the crystal dimensions, the type of oscillation involved, and the orientation of the plate cut from the natural crystal.

PROPERTIES OF PIEZOELECTRIC RESONATOR

A good piezoelectric resonator possesses the following properties: a low-temperature coefficient of resonant frequency, a high piezoelectric activity (PI), and a frequency spectrum containing only one resonant frequency in the vicinity of the desired oscillation. Temperature can alter the frequency of mechanical resonance through its effects on the density, the linear dimensions, and the moduli of elasticity of the crystal. Since some of the elastic constants are positive and others are negative, the temperature coefficient of frequency may be either positive, negative, or zero, according to the mode of oscillation, the orientation of the crystal plate, and the shape of the plate. The electrical circuit associated with a vibrating crystal is shown in Figure 4. The capacity C_0 represents the electrostatic capacity between the crystal electrodes when the crystal is in place but not vibrating; the series combination of L, C, and R represents the equivalent mass, compliance, and frictional loss of the vibrating crystal, respectively.

MEASUREMENT

STATIC CAPACITANCE (C_0)

The value of the static capacitance of the crystal unit may be measured by any conventional capacitance measuring unit. If this measurement is made with the use of a Q meter or an rf bridge, be careful to select a frequency of operation somewhat lower than the crystal unit frequency. Figure 4 shows the parameters of a quartz crystal.

RESONANCE AND ANTI-RESONANCE RESISTANCE

The measurement of the effective resistance in ohms at resonance is outlined in the operation procedure. The measurement of the effective resistance in ohms at anti-resonance is also outlined in the operation procedure.

MEASUREMENT OF MOTIONAL CAPACITANCE C_1, INDUCTANCE L_1, AND CRYSTAL Q

The frequency of anti-resonance (f_rL) with a given load capacitor (C_L) in series with the crystal unit and the equivalent substitution resistance are first measured with the Model 541C. The frequency of resonance (f_r) and the equivalent substitution resistance are then measured. Measure C_0 on a capacitance bridge. With these data the motional capacitance C_1, motional inductance L_1 and the crystal Q can be calculated with the following equations:

$$C_1 = \frac{2(C_0 + C_L)(f_{rL} - f_r)}{f_r}$$

$$L_1 = \frac{1}{4\pi^2 f_s^2 C} \qquad f_s \cong f_r$$

$$Q = \frac{2\pi f_s L_1}{R_1}$$

CRYSTAL DRIVE LEVEL

The amount of power dissipated in the crystal unit at resonance is a measure of the montional excursions of the crystal. The power is calculated by the equation:

$$P = \frac{E^2}{R}$$

where,
E is the voltage across an appropriate substitution resistor (R). R is the substitution resistor equal to the effective resonance resistance of a "series resonant" crystal unit or the effective resonant resistance of the combination of an "anti-resonant" crystal unit in series with a load capacitance.

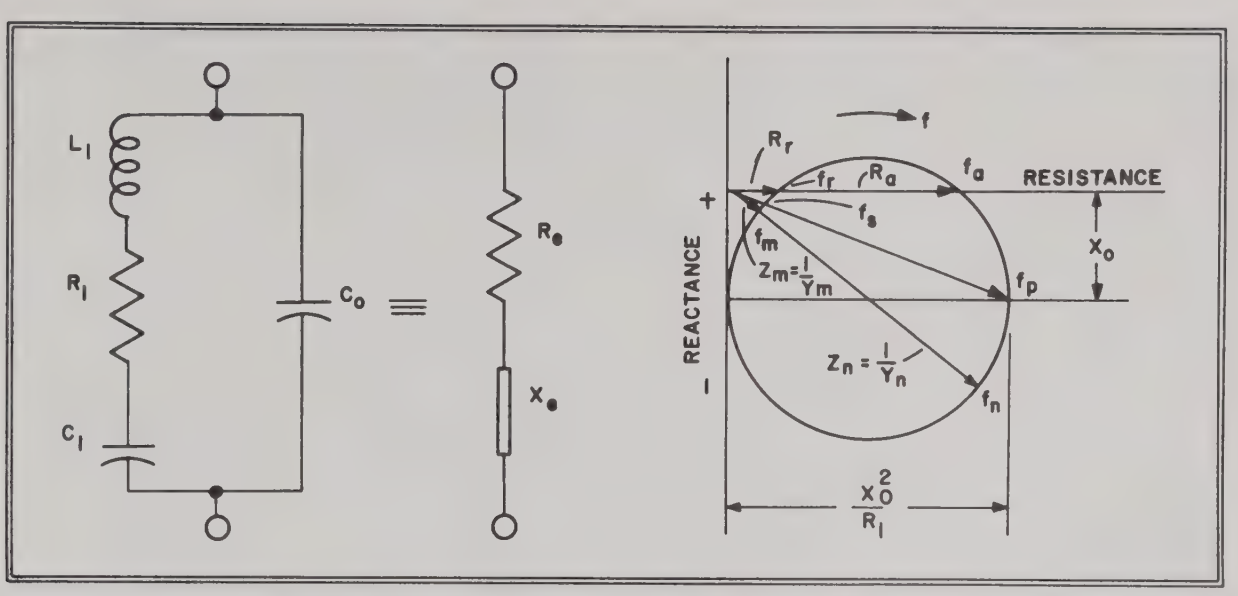


Figure 4. Equivalent Electrical Circuit and Vector Diagram of a Piezoelectric Crystal.

C_1 = Motional Capacitance

L_1 = Motional Inductance

R_1 = Motional Resistance

C_o = Shunt (Parallel) Capacitance

$r = \frac{C_o}{C_1}$ Capacitance Ratio

f_m = Frequency at Minimum Impedance

f_s = Motional (Series) Resonance Frequency = $\frac{1}{2\pi\sqrt{L_1 C_1}}$

f_r = Resonance Frequency (Reactance $X_e = 0$)

f_a = Anti-resonance Frequency (Reactance $X_e = 0$)

f_p = Parallel Resonance Frequency = $\frac{1}{2\pi}\sqrt{\frac{1}{L_1 C_1}\left(1+\frac{1}{r}\right)}$

f_n = Frequency at Maximum Impedance

$Z = \frac{1}{Y} = R_e + jX_e$ = Impedance of Vibrator

Z_m = Impedance at f_m (Minimum Impedance)

Z_n = Impedance at f_n (Maximum Impedance)

R_r = Impedance at f_r, Resistive (Resonance Resistance)

R_a = Impedance at f_a, Resistive (Anti-resonance Resistance)

$Q = \frac{\omega_s L_1}{R_1}$ = Quality Factor

and

$M = \frac{Q}{R} = \frac{1}{\omega_s C_o R_1}$ = Figure of Merit $= \frac{X_o}{R_1}$

where

$\omega = 2\pi f$; $X_o = \frac{1}{\omega_s C_o}$

L_o = Inductance in Parallel with Vibrator

C_L = Load Capacitance

R_{st} = Standard Resistor

f_{mT} = Frequency of Maximum Transmission

f_{sL} = Motional Resonance Frequency of Combination of Vibrator and C_L

f_{mTL} = Frequency of Maximum Transmission of Combination of Vibrator and C_L

R_{1L} = Resulting Motional Resistance of Combination of Vibrator and C_L

f_{rL} = Resonance Frequency of Combination of Vibrator and C_L

CRYSTAL IMPEDANCE METER

The Model 541C is designed to measure the equivalent circuit parameters of piezoelectric crystals in the frequency range of 2.5 to 1100 Hz. The unit consists of the following four main circuits: Oscillator; Voltmeter; Ohmmeter; Power Supply.

OSCILLATOR

The oscillator consists of a 6005 driver amplifier tube (V1) which can supply a 25-volt maximum undistorted sine wave signal to the input of the PRESET INPUT LEVEL control (R4). At this control the signal may be divided down to obtain the proper drive voltage for the crystal network. The signal is then applied directly to the crystal unit under test or to the crystal through the calibrated load capacitor (C3, C13, C14). This selection is made by the position of the A-R switch (S2). At this point a calibrating resistor may be substituted for the crystal unit, or crystal and load capacitor, to determine the resonance or anti-resonance resistance of the crystal unit. From there it is applied to the terminating resistors R5, R6, depending on the position of the TERM. RES. switch (S1). The GAIN control (R8) adjusts the loop gain. The signal is then impressed upon the grid of a 5749 phase-inverter-amplifier tube (V2). Tuning is accomplished by varying capacitor C6 which resonates with L_1 to L_7; the proper coil being selected for each of seven ranges. To complete the oscillator loop, the signal is returned from the plate of the 5749 tube through coupling capacitor C8 to the grid of the 6005 tube.

An added feature of the oscillator is an automatic gain control to compensate for the rapid increase in the amplitude of oscillation as the crystal unit starts to oscillate. This circuit consists of a resistor R12 and diode CR1 connected to R4. This varies the bias on the grid of the 5749 with a polarity which reduces the gain of the tube as the oscillation increases.

VOLTMETER

The voltmeter circuit consists of a 5726 dual diode V7, 5751 dual triode V3, the front panel meter (M1), and a zero adjusting potentiometers R30 and R47. One half of

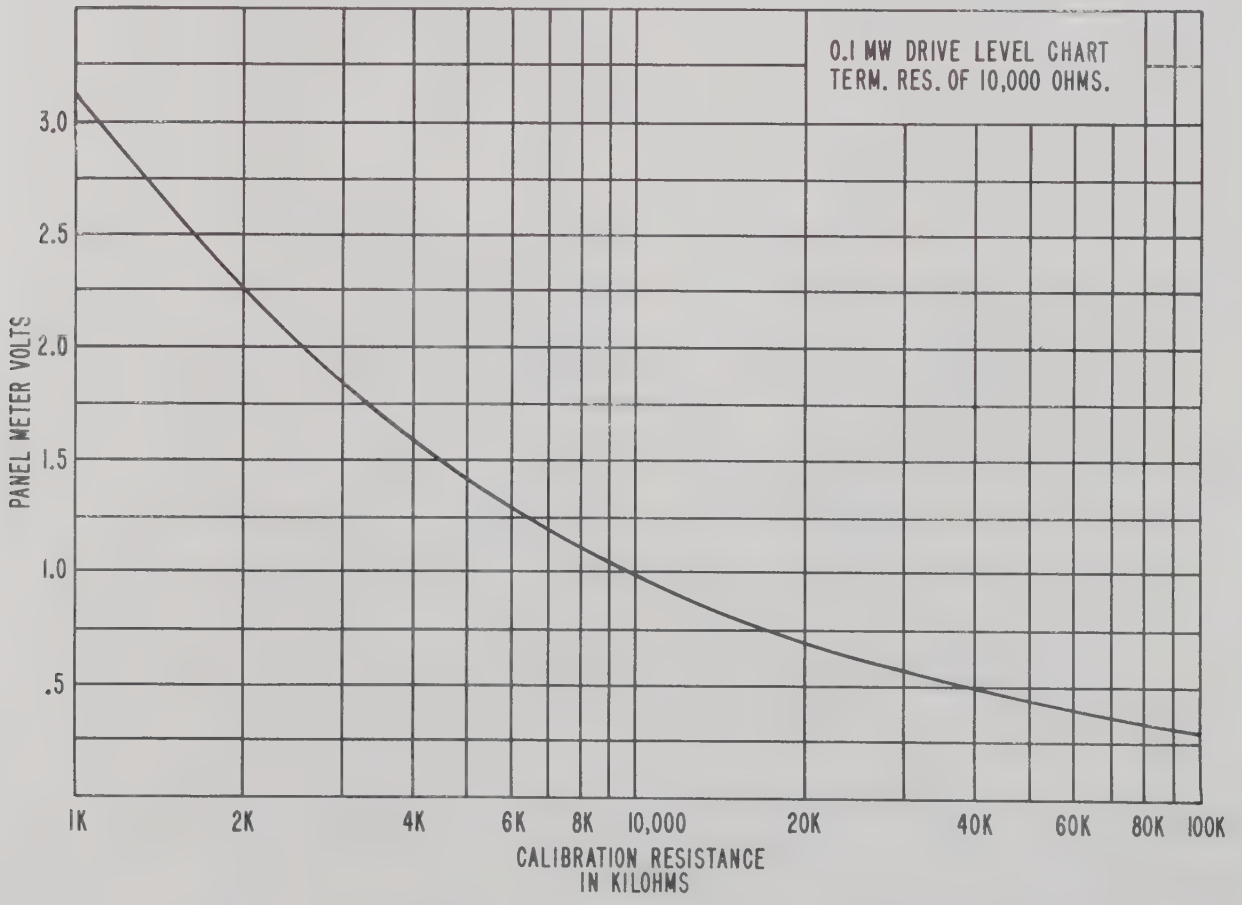


Figure 5. Drive Level Chart for 0.1 MW.

the 5726 is used as a signal rectifier, the other half is used to compensate the zero for variations in filament voltage. The DC output of the rectifier circuit is attenuated for the various voltage ranges with the dual dividers wired to TERM. RES. VOLTS FULL SCALE switch S7. Dual triode V3 is connected as a cathode follower to provide current to the front panel meter. Potentiometer R47 is used to balance the characteristics of V3 at zero. Potentiometer R30 balances the dual diode V7 at zero signal input and maximum sensitivity. The full scale meter calibration is controlled by potentiometer R22.

OHMMETER

The ohmmeter consists of a voltage divider system that reduces the regulated potential of 150 volts to the voltage necessary to actuate the meter for the resistance range selected. The SELECTOR switch makes available three resistance ranges R x 1, R x 10, and R x 100. These are read on the single 1000-ohm center scale of the meter.

The lower resistance branch of the voltage dividers is made adjustable so that the center scale reading (1000) may be calibrated for each range. The combination of these three variable resistors and the OHMMETER ZERO ADJUST control allows the ohmmeter to be adjusted at half and full scale, on each range, for accurate resistance calibration.

Across the OHMMETER socket is a normally closed switch (S5). When the SELECTOR switch is turned to one of the ohmmeter positions, the meter will read zero or can be adjusted to do so, because of this closed switch. The insertion of an adapter into the OHMMETER socket automatically opens this switch and allows the circuit to read the resistance of the adapter.

POWER SUPPLY

The power supply is designed to operate from a 115 or 230-volt, 50 to 1000 Hz source. A single section choke input filter is followed by a voltage regulator consisting of an OB2 and an OA2 tube connected in series and providing 255 volts. The regulator is followed by an RC decoupling filter.

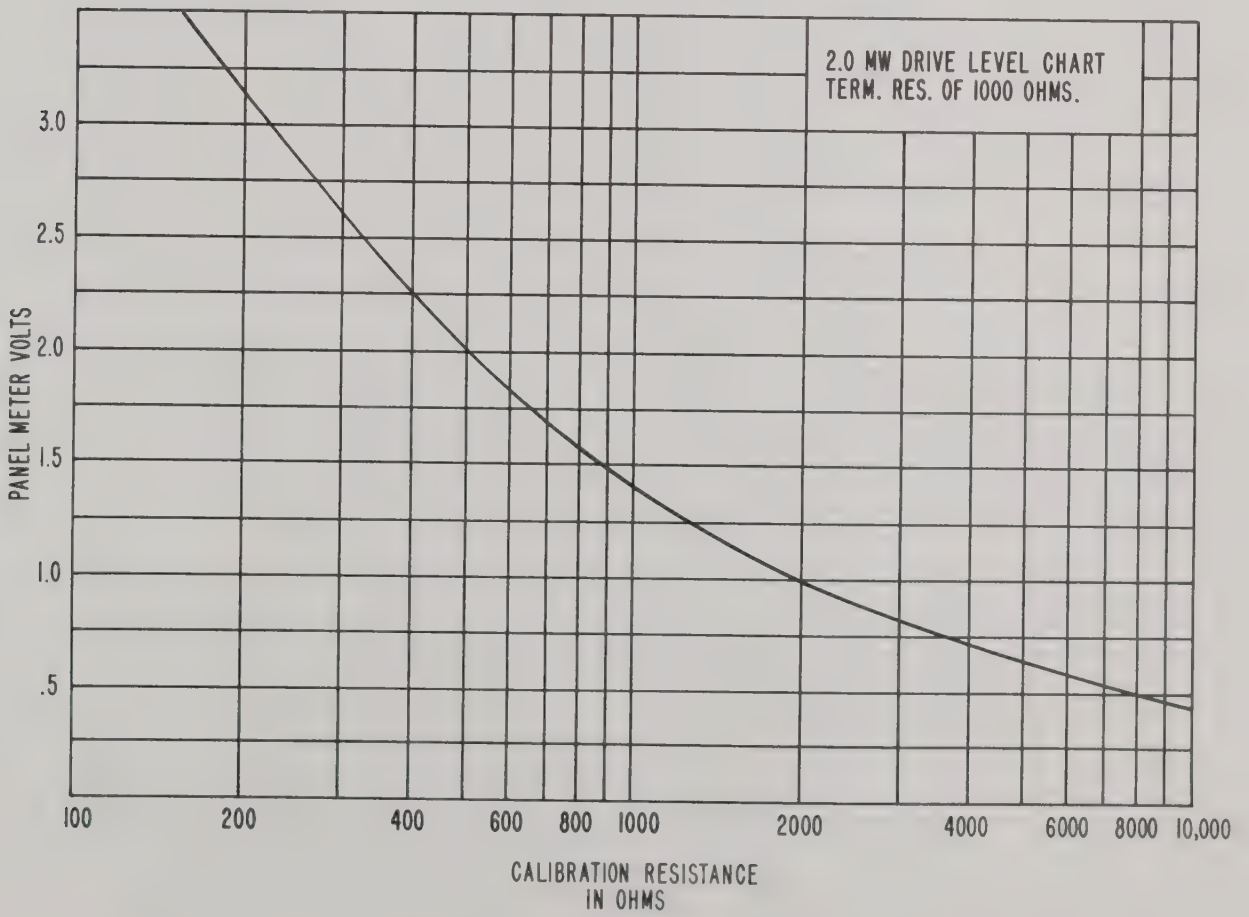


Figure 6. Drive Level Chart for 2.0 MW.

MILITARY CRYSTAL REFERENCE CHART

CRYSTAL UNIT MIL-C-3098	FREQUENCY RANGE (kHz)	FREQUENCY TOLERANCE (%)	RESONANCE CONDITION	MAXIMUM RESISTANCE (ohms)	DRIVE (MW)	TERMINATING RESISTOR (ohms)
CR-15 B/U (CR-29A/U is same as CR-15B/U except ±.002% tolerance.)	80-120	±.01	A(32.0 pf)	5K	2.0±.4	1000
	120-160	±.01	A(32.0 pf)	5.5K	2.0±.4	1000
	160-200	±.01	A(32.0 pf)	6.0K	2.0±.4	1000
CR-16B/U (CR-30A/U is same as CR-16B/U except .002% tolerance)	80-120	±.01	R	2K	2.0±.4	1000
	120-150	±.01	R	2.25K	2.0±.4	1000
	150-200	±.01	R	2.5K	2.0±.4	1000
CR-25A/U (CR-26A/U is same as CR-25A/U except .002% tolerance.)	200-225	±.01	R	2.5K	2.0±.4	1000
	225-265	±.01	R	3.0K	2.0±.4	1000
	265-290	±.01	R	3.5K	2.0±.4	1000
	290-330	±.01	R	4.0K	2.0±.4	1000
	330-370	±.01	R	4.5K	2.0±.4	1000
	370-410	±.01	R	5.0K	2.0±.4	1000
	410-425	±.01	R	5.5K	2.0±.4	1000
	425-460	±.01	R	6.5K	2.0±.4	1000
	460-500	±.01	R	7.5K	2.0±.4	1000
CR-37A/U	90-170	±.02	A(20.0 pf)	5K	2.0±.4	1000
	170-250	±.02	A(20.0 pf)	5K	2.0±.4	1000
CR-38 A/U	16-50	±.012	A(20.0 pf)	110K	.1	10,000
	50-80	±.012	A(20.0 pf)	100K	.1	10,000
	80-100	±.012	A(20.0 pf)	90K	.1	10,000
CR-39/U	160-250	±.004	R	150	.1	100
	250-330	±.004	R	600	.1	100
CR-40/U	160-250	±.003	R	150	.1	100
	250-330	±.003	R	600	.1	100
CR-42 A/U	90-170	±.003	A(32.0 pf)	4.5K	2.0	1000
	170-250	±.003	A(32.0 pf)	5.0K	2.0	1000
CR-43 A/U	80-86	±.005	A(45.0 pf)	3.0K	2.0	1000
CR-45/U	455	±.02	R	3.3K	2.0	1000
CR-46A/U (CR-47A/U is same as CR-46A/U except .002% tolerance.) (CR-63A/U, essentially same test data as CR-46A/U.)	200-250	±.01	A(20.0 pf)	5.3K	2.0	1000
	225-275	±.01	A(20.0 pf)	6.0K	2.0	1000
	275-325	±.01	A(20.0 pf)	6.5K	2.0	1000
	325-375	±.01	A(20.0 pf)	7.0K	2.0	1000
	375-425	±.01	A(20.0 pf)	7.5K	2.0	1000
	425-475	±.01	A(20.0 pf)	8.0K	2.0	1000
	475-500	±.01	A(20.0 pf)	8.5K	2.0	1000
CR-50 A/U	16-30	±.012	R	100K	.1	10,000
	30-50	±.012	R	90K	.1	10,000
	50-70	±.012	R	80K	.1	10,000
	70-90	±.012	R	70K	.1	10,000
	90-100	±.012	R	60K	.1	10,000
CR-57/U	500	±.001	A(32.0 pf)	3K	.5	1000

MAINTENANCE

GENERAL

Periodic inspection should be made to see that all screws and nuts are tight. If trouble should develop in the panel meter (M1), it should be replaced from the factory and no attempt made to repair it.

If the tuning dial should become loose and slip, it is only necessary to rotate the variable capacitor to its maximum capacity and align the dial at the low frequency scale-end mark. To obtain better correlation, the dial may be rotated slightly in either direction so that all scales are approximately alighed. The dial is not to be used for precise frequency measurement, but only to approximate the crystal unit's frequency until it starts to oscillate.

The LOAD CAPACITOR dial is more critical and should it become loose and slip it is necessary to recalibrate the capacitor. Since this capacitor is calibrated to better than ±0.1 pf, the Model 541C should be sent back to the factory for recalibration unless proper calibration equipment is available.

LOAD CAPACITANCE

The load Capacitance Chart is prepared from data obtained by measuring the actual capacitance value (within ±0.1 pf) of the load capacitor in the circuit with the R-A switch in the A position. The equipment required is a 400 KC crystal oscillator controlling a Q meter (Boonton Radio type 100-A, or equal) and a precision capacitor (General Radio type 722-D, or equal). The wiring between the units must be #12 AWG solid copper wire supported on 2-inch centers. The connections to the Model 541C are as follows: the high lead of the precision capacitor goes to the set screw in the R-A switch knob and the ground side goes into the left contact (as you face the equipment) of the CRYSTAL socket. The fixed capacitors are set to 20 and 32 pf in the same setup.

The Q meter is tuned to resonance by using a standard inductance coil with the precision capacitor set at 200 pf and the LOAD CAPACITOR dial set at zero. The LOAD CAPACITOR dial is then moved 1 division up at a time from 0 to 10 on the dial, 2 divisions from 10 to 30, and 5 divisions from 30 to 100; the Q meter is retuned to resonance at each point with the precision capacitor. The difference in reading of the precision capacitor is the value of the load capacitor at each dial setting.

ADJUSTMENTS

There are eight adjustments on the Model 541C that may be made in the field. The eight potentiometer adjustments may be reached from the top of the chassis by removing the top dust cover.

VOLTMETER & PRESET INPUT LEVEL

(1) Loosen the shaft lock on R22 and R30.

(2) With power on and the unit not oscillating, the voltmeter electrical zero may be adjusted by placing the TERM. RES. VOLTS FULL SCALE switch S7 to the 25-volt position, adjust V3 balancing potentiometer R47 METER ZERO for zero on the panel meter.

(3) Set TERM. RES VOLTS FULL SCALE switch S7 to the 0.5 volt range and adjust V7 balancing potentiometer R30 for zero on the panel meter.

(4) With LOAD CAPACITY switch set to R, TERM. RES. OHMS switch S1 set to 1000 ohms, GAIN potentiometer R8 full counterclockwise, FREQUENCY RANGE KILOCYCLES set 10-25, TUNING knob set to the extreme clockwise position (under 10KC), TERM. RES. VOLTS FULL SCALE switch set to 0.5 volts, insert a 10K plug-in resistor into the crystal socket and insert the probe of a Ballantine VTVM Model 314 or equal into the front panel jack J5.

(5) Advance PRESET INPUT LEVEL potentiometer R4 full clockwise.

(6) Adjust GAIN potentiometer R8 for a reading of 0.5 volts on the Ballantine VTVM.

(7) Adjust VTVM full scale adjust potentiometer R22 for a full scale reading on the panel meter. Check 1.0 volt for full scale reading on the panel meter ±5%. Insert a 1000-ohm plug-in resistor in the crystal socket. Set the TERM. RES. OHMS to 10,000 ohms. Check the 2.5, 5.0 and 10 volts for full scale reading on the panel meter ±5%.

(8) Tighten the shaft locks and recheck.

(9) Set the FREQUENCY RANGE KILOCYCLES switch to 450-1100 (frequency under 450 KC).

(10) Set TERM. VOLTS FULL SCALE switch S7 to 0.5 volts, insert a 10K plug in resistor in the crystal socket. Set TERM. RES. OHMS switch S1 to 1000 ohms. Return PRESET INPUT LEVEL potentiometer R4 to full counterclockwise position and advance GAIN potentiometer R8 to full clockwise position.

(11) Adjust PRESET INPUT LEVEL potentiometer R4 for 0.5 volts on the panel meter (also on the Model 314 Voltmeter) and lock the potentiometer. Cover access hole to the PRESET INPUT LEVEL potentiometer.

OHMMETER

(1) Loosen shaft locks on R24, R26, R28.

(2) a. Set SELECTOR switch to R x 100.

b. Insert a calibrated 100K resistor into the OHMMETER socket.

c. Rotate the OHMMETER ZERO ADJUST control to its center position.

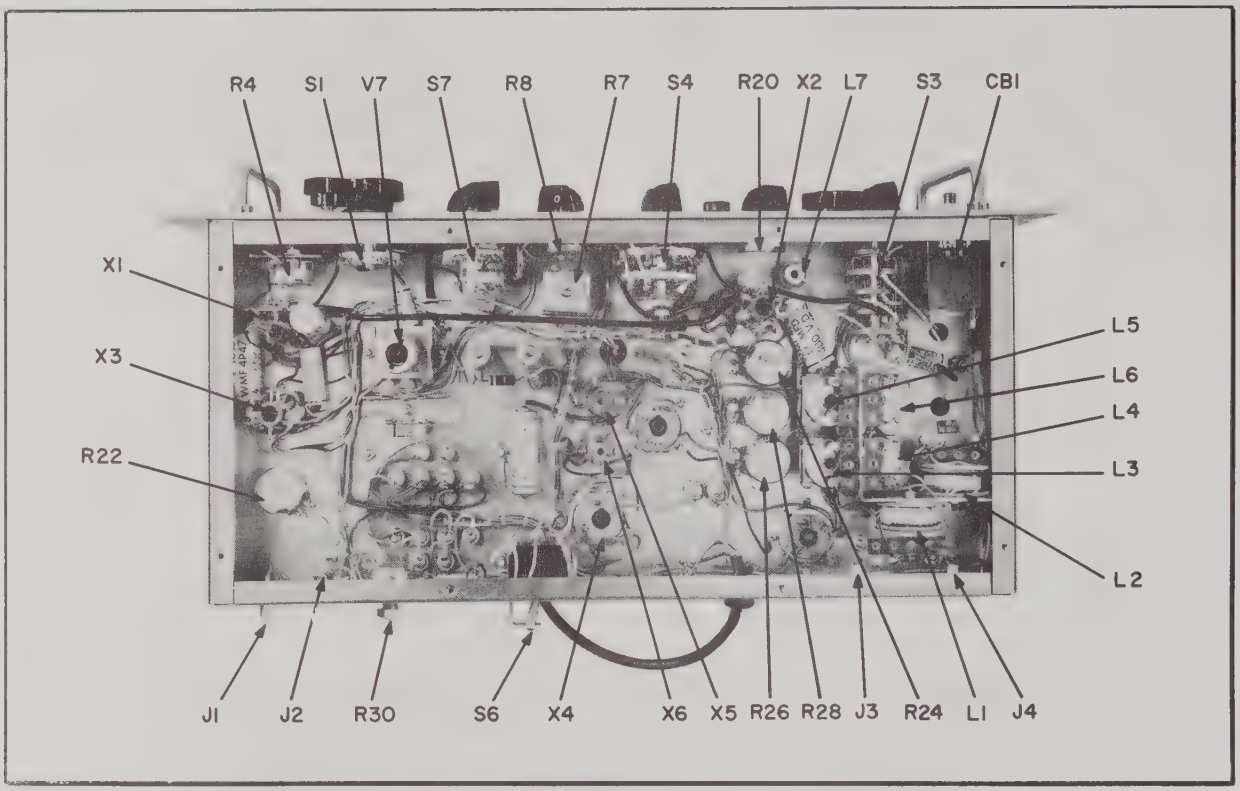


Figure 7. Bottom View of Chassis of Crystal Impedance Meter Model 541C.

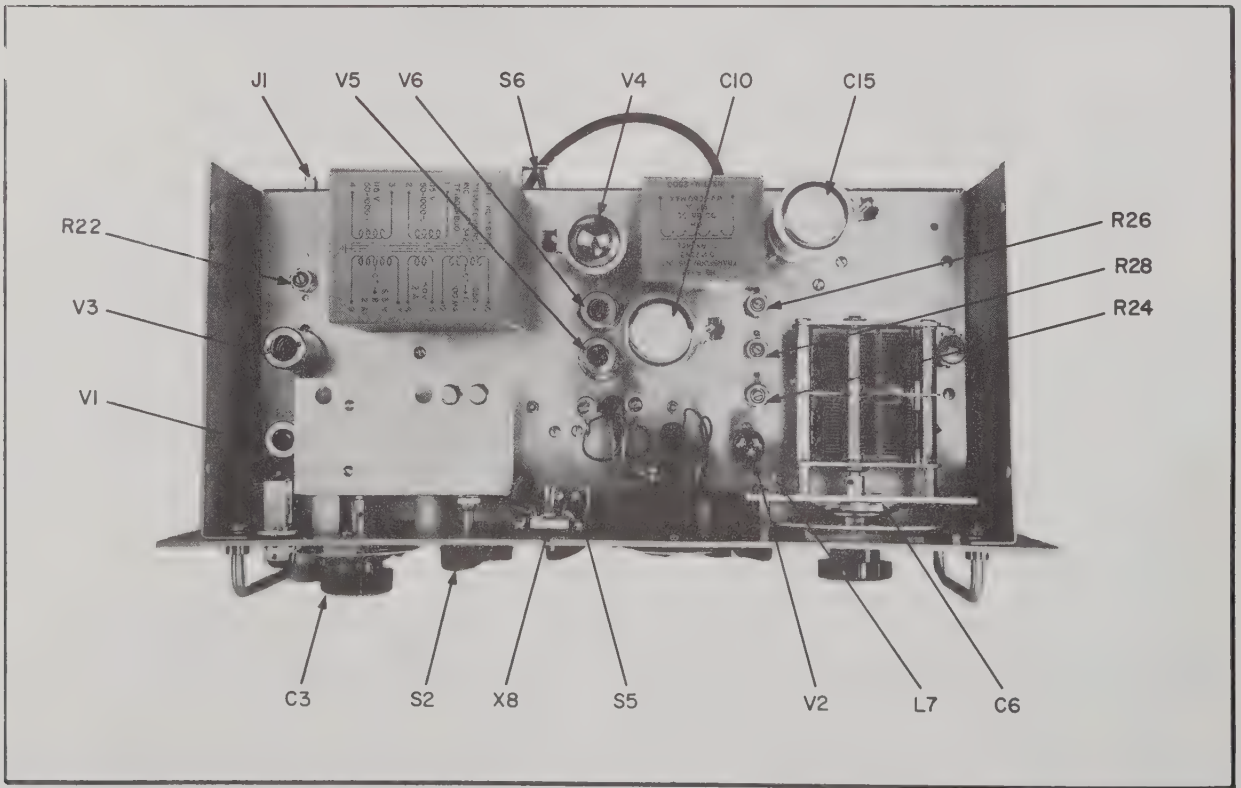


Figure 8. Top View of Chassis of Crystal Impedance Meter Model 541C.

d. Depress the button under the OHMMETER socket and adjust R26 for a 100K (1000 x 100) reading.

e. Release button and adjust the OHMMETER ZERO ADJUST control for zero.

f. Repeat steps (d) and (e) until the ohmmeter reads 100K with the button down and zero with the button released.

(3) a. Set SELECTOR switch to R x 10.

b. Insert a calibrated 10K resistor into the OHMMETER socket.

c. Depress button and adjust R28 for a 10K (1000 x 10) reading.

d. If necessary, readjust the OHMMETER ZERO ADJUST control for a zero reading.

e. Repeat steps (c) and (d) until the ohmmeter reads 10K with the button depressed and zero with the button released.

(4) a. Set SELECTOR switch to R x 1.

b. Insert a calibrated 1K resistor into the OHMMETER socket.

c. Depress the button and adjust R24 for a 1K reading.

d. If necessary, readjust the OHMMETER ZERO.

e. Repeat steps (c) and (d) until the ohmmeter reads 1K with the button depressed and zero with the button released.

(5) Tighten the three shaft locks and recheck.

CRYSTAL CURRENT SENSITIVITY, 10,000 OHMS

(1) Connect a Wheatstone between J5 and ground with TERM. RES. switch S1 in 10,000 ohm position.

(2) Adjust R7 for a reading of 10,000 ohms ±0.5%.

TROUBLE SHOOTING

WARNING

When servicing the crystal impedance meter Model 541C be extremely careful. High voltage is present. Always disconnect the line plug before making resistance checks in the meter. Before touching any part after the voltage is shut off, short the part to chassis.

TROUBLE SHOOTING PROCEDURES

(1) Sectionalization and Localization - The first step in servicing a defective test equipment is to sectionalize the fault. Sectionalization means tracing the fault to the major component or circuit responsible to the abnormal operation of the set. The second step is to localize the fault. Localization means tracing the fault to the defective part responsible for the abnormal condition. Some faults, such as burned out resistors and shorted transformers, can be located by sight or smell. The majority of faults may be located by checking voltage and resistance.

(2) Tests - The tests listed below aid in isolating the source of trouble. Remember that servicing procedure should cause no further damage to the test equipment. First, trouble should be localized to a single stage or circuit in the equipment. Then the trouble may be isolated within the stage or circuit by appropriate voltage, resistance and continuity measurements.

Through this inspection alone the repairman frequently discovers the trouble or determines the stage in which the trouble exists. This inspection is valuable in order to avoid additional damage which might occur through improper servicing methods and to forestall future failures.

(3) Operational Tests - The operational tests are important because they frequently indicate the general condition of trouble. In many instances this information will indicate the exact nature of the fault. In order for this information to be utilized fully, all symptoms must be interpreted in relation to another.

The trouble shooting symptoms listed in the chart on page 20 will aid in localizing trouble.

(4) Intermittents - In all these tests the possibility of intermittents should not be overlooked. This type of trouble may appear when the set is tapped or jarred. Look for loose connections. It is possible that the trouble is not in the set itself but in the installation, such as cord connections, etc.

VOLTAGE MEASUREMENTS

Voltage measurements are an almost indispensable aid to the repairman, because most trouble either results from abnormal voltages or produces abnormal voltages. Voltage measurements are always made between two points in the circuit and the circuit need not be interrupted. Complete information on normal operating voltages is given in the chart on page 18.

(1) Unless otherwise specified, voltages are measured between the indicated points and ground.

(2) Always begin by setting the voltmeter on the highest range in order that the voltmeter will not be overloaded and then, if necessary, set the voltmeter to a lower range.

Table 3. Resistance Chart (Typical values)

TUBE	LOCATION	PIN - 1	PIN - 2	PIN - 3	PIN - 4	PIN - 5	PIN - 6	PIN - 7	PIN - 8	PIN - 9
6005	X1	100 K	270	0.1	0.1	300 K	300 K	100 K		
5749	X2	330 K	68	0.1	0.1	300 K	400 K	68		
5751	X3	300 K	1M	1500	0.1	0.1	300 K	1M	1500	0.1
5Y3W	X4	N.C.	300 K	N.C.	305	N.C.	305	N.C.	300 K	
0B2	X5	300 K	N.C.	N.C.	N.C.	300 K	N.C.	150 K		
0A2	X6	150 K	N.C.	N.C.	N.C.	150 K	N.C.	0		

Resistance (in ohms) to Ground

K = 1000 ohms
M = 1 megohm

Table 4. Voltage Chart

SELECTOR switch in OPERATE position

CRYSTAL socket open

TUBE	LOCATION	PIN - 1	PIN - 2	PIN - 3	PIN - 4	PIN - 5	PIN - 6	PIN - 7	PIN - 8	PIN - 9
6005	X1	0	11	3.15 AC	3.15 AC	70	228	0		
5749	X2	-.2	.42	3.15 AC	3.15 AC	227	50	.42		
5751	X3	250	0	2.6	3.15 AC	3.15 AC	250	0	2.6	3.15 AC
5Y3W	X4	N.C.	420 *	N.C.	525 AC	N.C.	525 AC	N.C.	420 *	
0B2	X5	250	N.C.	N.C.	N.C.	250	N.C.	147		
0A2	X6	147	N.C.	N.C.	N.C.	147	N.C.	0		

* AC filament voltage of X4 measured between pins # 2 and # 8 = 5.0 volts.

All measurements taken to ground with a 20,000 ohms-per-volt multimeter.

(3) In checking cathode voltage remember that a reading can be obtained when the cathode resistor actually is open. The resistance of the meter may act as the cathode resistor, thus the cathode voltage may be approximately normal only as long as the voltmeter is connected between cathode and ground. An abnormally high plate voltage may indicate an open cathode resistor.

VOLTMETER LOADING

It is essential that the voltmeter resistance be at least ten times as large as the resistance of the circuit across which the voltage is measured. If the voltmeter resistance is comparable to the circuit resistance, the voltmeter will indicate a voltage lower than the actual voltage present when the voltmeter is removed from the circuit.

(1) To minimize voltmeter loading in high resistance circuits, use the highest voltmeter range. The decreased loading caused by the voltmeter will more than compensate for the inaccuracy which results from reading only a small deflection on the scale of the voltmeter.

(2) The voltage and resistance charts (Tables 3 and 4) are based on typical readings taken with a 20,000 ohms-per-volt meter. The resistance values can vary ±20% between units. If a 20,000 ohms-per-volt meter is used in testing for the voltage, it is not necessary to consider the effect of loading.

RESISTANCE MEASUREMENTS

When a fault develops in a circuit, its effect will very often show up as a change in the resistance values. Table 3 indicates the normal resistance values as measured at the tube sockets. These values are measured between the indicated points and ground unless otherwise stated. Before making any resistance measurements, turn off the power. If the ohmmeter is connected to a circuit which already has voltage in it, the meter may be damaged.

CAUTION

ALWAYS DISCHARGE HIGH VOLTAGE CAPACITORS BEFORE MAKING RESISTANCE MEASUREMENTS.

TUBE CHECKING

Tube faults are responsible for a large percentage of the failures which occur in test equipment. In putting a new tube into the voltmeter circuit, it may be necessary to realign the voltmeter.

GENERAL PRECAUTIONS

Whenever the Model 541C is serviced, carefully observe the following precautions:

a. Be careful when the instrument is removed from its cabinet, dangerous voltages are exposed.

b. Careless replacement of parts often causes new faults. Therefore, observe the following points.

(1) Before a part is unsoldered, note the position of the leads. If the part, such as a transformer, has a number of connections tag each of the leads to it.

(2) Be careful not to damage other leads by pulling or pushing them out of the way.

(3) Do not allow drops of solder to fall into the equipment, since they may cause short circuits.

(4) A carelessly soldered connection may create a new fault. It is very important to make well-soldered joints, since a poorly soldered joint is one of the most difficult faults to find.

(5) Do not disturb the adjustments of the controls with the screwdriver slots.

TROUBLE SHOOTING CHART

Table 5 Trouble Shooting Chart is supplied as an aid in locating trouble. This chart lists the symptoms which the repairman observes while making a few simple tests. The chart also indicates how to localize trouble quickly to individual stages. Once the trouble has been localized to a stage or circuit, voltage and resistance measurements of this stage or circuit ordinarily should be sufficient to isolate the defective part. Normal voltage and resistance measurements are given in Tables 3 and 4.

Table 5. Trouble Shooting Chart

SYMPTOM	POSSIBLE TROUBLE	CORRECTION
SELECTOR switch in OPERATE position.		
1. Pilot lamp does not light, unit inoperative.	a. Cord not plugged into AC power source or line cord open.	a. Insert power plug into power line outlet.
	b. Circuit breaker defective.	b. Check and replace if defective.
	c. ON-OFF switch defective (Part of S4).	c. Check and replace if defective.
	d. Voltage Change-Over switch defective.	d. Check and replace if defective.
	e. Transformer T1 open.	e. Check and replace if defective.
2. Pilot lamp lights dimly (on 115-volt source).	a. Voltage Change-Over switch S6 set for 230 V operation.	a. Set correctly.
3. Unit operates, voltmeter is off-scale to the right or left, zero can not be obtained.	a. 5751 tube (V3) defective.	a. Test tube and check tube socket voltages.
	b. 5726 tube (V7) defective. Check resistor associated with V3 and V7.	b. Check the components, if defective, replace.
	c. Defective contact on switch S4.	c. Check and replace if defective.
4. Unit not oscillating, voltmeter reads up scale, zero can not be adjusted.	a. R47 defective.	a. Check and replace if defective.
	b. Defective contact on switch S4.	b. Check and replace if defective.
5. Voltage regulator tubes do not light.	a. Rectifier tube V4 defective.	a. Test and replace if defective.
	b. Regulator tubes V5 or V6 defective.	b. Test and replace if defective.
	c. High voltage winding of T1 open, rectifier tube filament winding open.	c. Check and replace T1 if defective, check ground on pin #11 of T1.
	d. L3 open.	d. Check and replace if defective.
	e. R18 or R19 open.	e. Check and replace if defective.
	f. C15, C18, C19 shorted.	f. Check and replace if defective.
6. No reading or deflection of voltmeter with calibrating resistor in CRYSTAL socket.	a. GAIN control set too low.	a. Advance control clockwise.
	b. A-R switch at A.	b. Turn to R position.
	c. Meter defective.	c. Check and replace if defective.
	d. Calibrating resistor open.	d. Check resistor.
	e. Wiring shorted or open.	e. Check continuity.
	f. 6005 tube (V1) defective.	f. Test tube and replace if defective.
	g. 5749 tube (V2) defective.	g. Test tube and replace if defective.

Table 5. Trouble Shooting Chart (Continued)

SYMPTOM	POSSIBLE TROUBLE	CORRECTION
	h. Resistor open or a capacitor open or shorted.	h. Check components in oscillator circuit. Measure the voltage and resistance at the tube socket pins.
7. Voltmeter inaccurate	a. Voltmeter zero and full-scale adjust controls not set properly.	a. Readjust voltmeter as per the procedure in the book.
	b. Voltmeter tube 5751 (V3) defective.	b. Test tube and replace if defective.
	c. Meter defective.	c. Check meter and replace if defective.
	d. Too small a value of resistance in CRYSTAL socket.	d. Use minimum value of resistance as per figures 5 and 6.
8. Unit operates erratically, amplitude of oscillation increases very rapidly when using a crystal unit.	a. Defect in AGC circuit.	a. Check R10, R11, R12. Check silicon diode CR1.
9. Ohmmeter does not work.		
a. With OHMMETER socket open, no zero ohm reading obtained on any range.	a. Switch S5 defective.	a. Check switch and replace if defective.
	b. Defective 0A2 tube (V6).	b. Test tube and replace if defective.
	c. Switch S4 defective.	c. Check switch and replace if defective.
	d. OHMMETER ZERO ADJUST control not properly set.	d. Rotate control for a zero ohm reading.
b. Ohmmeter works on two ranges only.	a. Divider network associated with faulty range, defective.	a. Check fixed resistor R23, R25, R27, and variable resistor R24, R26, R28.
c. Ohmmeter inaccurate.	a. Divider network and/or OHMMETER ZERO ADJUST control not adjusted properly.	a. Align circuit as explained in the instruction book.
	b. Fixed resistors changed value R21, R23, R25, R27.	b. Check resistance values and replace if defective.
	c. Meter defective.	c. Check and replace if defective.
10. Excessive hum in output.	a. Open filter capacitor in power supply.	a. Check C10 by replacing it with a new capacitor.
	b. Heater to cathode short in V1 or V2.	b. Test tubes and replace if defective.
11. Intermittent operation.	a. Defective tube, resistor, or capacitor.	a. With an insulated prod, gently tap and move all tubes, resistors, capacitors, and soldered connections.

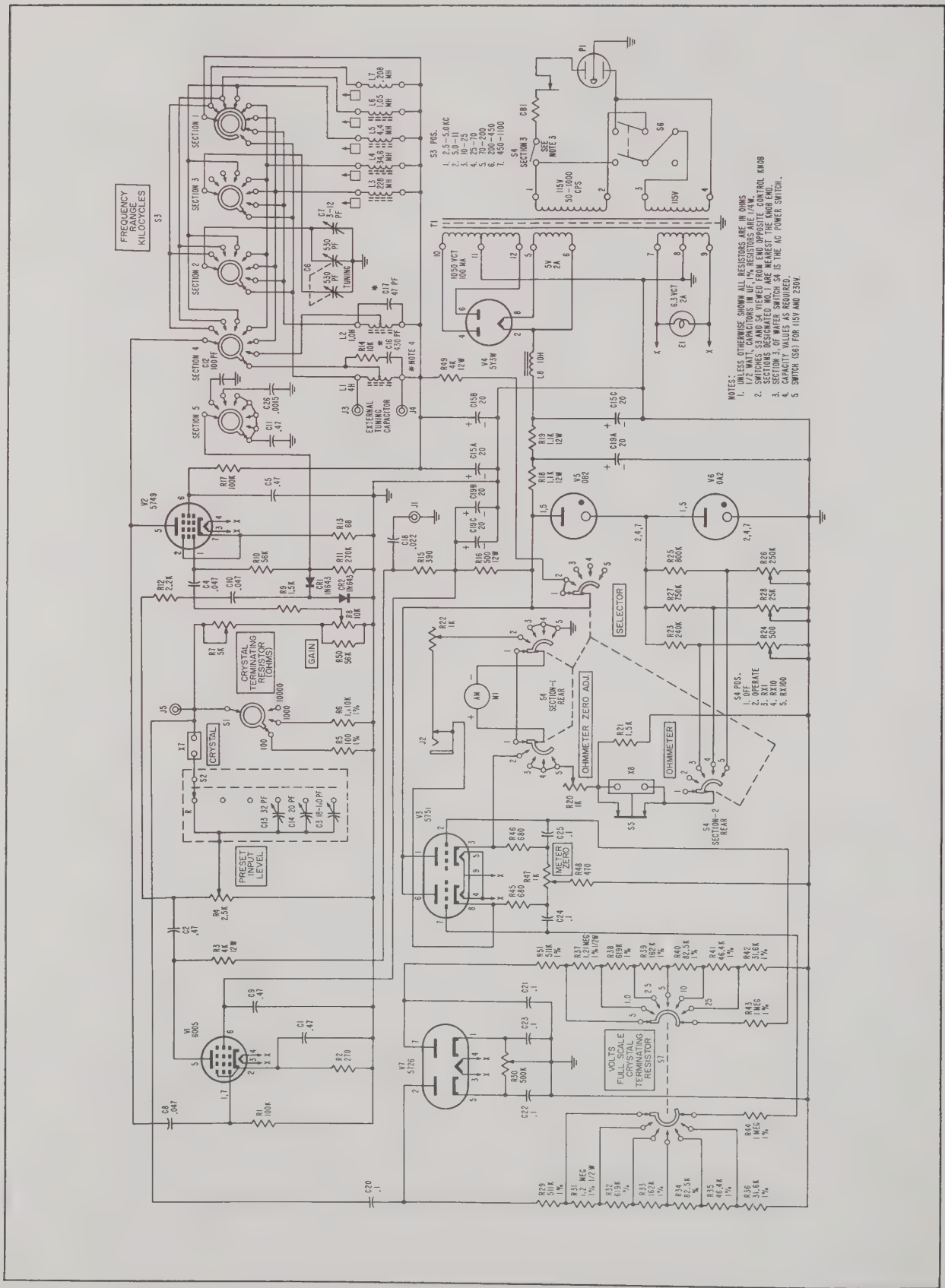


Figure 9. Schematic Diagram of Model 541C Crystal Impedance Meter.

Table 6. Table of Replaceable Parts

SYMBOL NO.	FUNCTION	DESCRIPTION	RFL PART NO.
C1	Cathode and screen bypass for V1. Cathode bypass for V3.	CAPACITOR, mylar, film encased: 0.47 μF; ±10%, 100 V.	H-1007-629
C2	Coupling between V1 and V2.	CAPACITOR, mylar, film encased: 0.47 μF; ±10%, 400 V.	H-1007-630
C3	Calibrated load capacitor.	CAPACITOR, variable: capacity, 105 pF max. -9.5 pF min.; 1000 V RMS, 60 c/s.	HA-5556
C4	DC isolation for crystal unit.	CAPACITOR, mylar, film encased: .047 μF; ±10%, 100 V.	H-1007-631
C5	Screen bypass for V2.	CAPACITOR, mylar, film encased: same as C2.	H-1007-630
C6	Tuning, adjustable.	CAPACITOR, variable: two-section, 14.5 to 539.5 pF per section. 31 plates per sec.	HA-6521
C7	Trimmer for C6.	CAPACITOR, variable: capacity, 3.0 pF min. to 12 pF max.	HA-5531
C8	Feedback coupling between V2 and V1.	CAPACITOR, mylar film encased: .047 μF; ±10%, 400 V.	H-1007-632
C9	Isolates DC from output jack J1.	CAPACITOR, mylar, film encased: same as C2.	H-1007-630
C10	Feedback coupling.	CAPACITOR, mylar, film encased: same as C4.	H-1007-631
C11	Tuned bypass.	CAPACITOR, mylar, film encased: same as C1.	H-1007-629
C12	Tuned bypass.	CAPACITOR, silver mica, dipped 100 pF, ±10%, 100 V.	H-1080-328
C13	Load capacitor.	CAPACITOR, variable: concentric, air-dielectric; 35 pF.	HA-8726
C14	Load capacitor.	CAPACITOR, variable: concentric, air-dielectric; 20 pF.	HA-8727
C15A, B and C	B + supply filter.	CAPACITOR, electrolytic: octal-base 20 x 20 x 20 μF, 450 V.	HA-11816
C16	Trimmer for L1.	CAPACITOR, mica; factory adjust, 500 V.	H-1080-
C17	Trimmer for L2.	CAPACITOR, mica; factory adjust, 500 V.	H-1080-
C18	Isolates DC from output jack J1.	CAPACITOR, mylar, film encased: .022 μF; ±10%, 400 V.	H-1007-634
C19	B + supply filter.	CAPACITOR, electrolytic: same as C15A.	HA-11816
C20	Coupling between V7 and X7.	CAPACITOR, mylar, film encased: 0.1 μF; ±10%, 100 V.	H-1007-624
C21	Plate bypass.	CAPACITOR, mylar, film encased: same as C20.	H-1007-624
C22	Cathode bypass.	CAPACITOR, mylar, film encased: same as C20.	H-1007-624

Table 6. Table of Replaceable Parts (Continued)

SYMBOL NO.	FUNCTION	DESCRIPTION	RFL PART NO.
C23	Cathode bypass.	CAPACITOR, mylar, film encased: same as C20.	H-1007-624
C24	Feedback coupling.	CAPACITOR, mylar, film encased: same as C20.	H-1007-624
C25	Feedback coupling.	CAPACITOR, mylar, film encased: same as C20.	H-1007-624
C26	Tuned bypass.	CAPACITOR, mylar, film encased: .0015 μF; ±10%, 100V.	H-1007-633
CB1	Protection in AC input circuit.	CIRCUIT BREAKER: 1 amp.	HA-11664
CR1 & CR2	AGC rectifiers.	DIODE, silicon 1N643.	HA-23327
E1	Indicator of power ON.	LAMP, incandescent: 6-8V, 0.15 amp; miniature bayonet base; brown bead.	HA-1045
E4	Tube shield for V2.	SHIELD, electron tube: locking type.	HA-4781
E5	Tube shield for V3.	SHIELD, electron tube: locking type.	HA-4782
E6	Tube shield for V1.	SHIELD, electron tube: locking type.	HA-4731
E7	Tube shield for V5.	SHIELD, electron tube: same as E6.	HA-4731
E8	Tube shield for V6.	SHIELD, electron tube: same as E6.	HA-4731
E9	Tube shield for V7.	SHIELD, electron tube.	HA-4730
E10	Operates S1.	KNOB: pointer; black bakelite.	HA-5224
E11	Operates S2.	KNOB: Same as E10.	HA-5224
E12	Operates S3.	KNOB: Same as E10.	HA-5224
E13	Operates S4.	KNOB: Same as E10.	HA-5224
E14	Operates R13.	KNOB: Same as E10.	HA-5224
E15	Operates R20.	KNOB: Same as E10.	HA-5224
E16	Operates C6.	KNOB: round, fluted; black plastic.	HA-6532
E17	Operates R49.	KNOB: round; black plastic.	HA-6538
E18	Operates R50.	KNOB: same as E17.	HA-6538
E19	Operates R51	KNOB: same as E17.	HA-6538
E20		KNOB: w/plain molded hole.	HA-1673
E21	Support for C9.	TERMINAL STRIP: 2 terminal; w/brass C.P. lugs and mtg. brackets.	HB-18142
E22	Support for R25, R27, and R29.	TERMINAL STRIP: 3 terminal.	HA-5570

Table 6. Table of Replaceable Parts (Continued)

SYMBOL NO.	FUNCTION	DESCRIPTION	RFL PART NO.
E23	Actuates S5.	ACTUATOR, bolted to subminiature switch S5.	HA-5528
E24	Power cable term.	TERMINAL STRIP: same as E21.	HB-18142
E25	L1 termination.	STRIP, terminal: 5-terminal.	HA-4819
E26	L2 termination.	STRIP, terminal: 3-terminal.	HA-11817
E27	L3 termination.	STRIP, terminal: same as E21.	HB-18142
E28	L4 termination.	STRIP, terminal: same as E21.	HB-18142
E29	L5 termination.	STRIP, terminal: same as E21.	HB-18142
E30	L6 termination.	STRIP, terminal: same as E21.	HB-18142
I1	Holder for indicator lamp.	LIGHT, indicator: w/lens; $\frac{1}{2}$" ruby jewel; for miniature bayonet base.	HA-3734
J1	RF output jack.	CONNECTOR, receptacle: coaxial; female.	HA-5535
J2	Crystal current.	JACK, telephone.	HB-3152
J3	External tuning capacitor.	JACK, nylon.	HA-7940
J4		JACK, nylon: same as J3.	HA-7940
J5		JACK nylon: same as J3.	HA-7940
L1	Tuning coil for 2.5 to 5.0KC.	COIL, toroid: 4 henries.	HB-17646-2
L2	Tuning coil for 5-10KC.	COIL, toroid: 1 henry.	HB-17646-1
L3	Tuning coil for 10-25KC range.	COIL, assembly: 228 mh.	HA-23325
L4	Tuning coil for 25-70KC range.	COIL, assembly: 34.6 mh.	HB-23324
L5	Tuning coil for 70-200KC range.	COIL, assembly: 4.4 mh.	HB-23322
L6	Tuning coil for 200-450KC range.	COIL, assembly: 1.05 mh.	HB-23323
L7	Tuning coil for 450-1100KC range.	COIL, slug tuned: center inductance 0.208 mh at 790KC.	HA-23326
L8	B + supply filter.	INDUCTOR, power: 10 hy, 90 ma DC, 180 ohms.	HA-6528
M1	Measures volts and ohms.	METER, ammeter: 0-100 μA .5/1.0/2.5	HB-23302

Table 6. Table of Replaceable Parts (Continued)

SYMBOL NO.	FUNCTION	DESCRIPTION	RFL PART NO.
O1	Holds tube V4 in its socket.	CLAMP, tube: stainless steel.	HA-4499
O2	Holds cap. C10 in its socket.	CLAMP, tube: stainless steel.	HA-6097
O3	Holds capacitor C15 in socket.	CLAMP, tube: same as O2.	HA-6097
P1	Power Cord.	LINE CORD.	HB-9361
P2	Connects RF cable to C. I. Meter.	CONNECTOR, plug: male.	HA-6781
R1	Grid return for V1.	RESISTOR, comp; 100K ± 5%, ½ W.	H-1009-348
R2	Cathode bias for V1.	RESISTOR, comp; 270 ohms ± 5%, 1 W.	H-1009-714
R3	Plate load for V1.	RESISTOR, WW; 4K ± 5%, 12 W.	H-1100-159
R4	Preset input.	RESISTOR, variable comp; 2500 ohms ± 10% 2 W.	HA-23317
R5	Crystal level term. resistor.	RESISTOR, film; 100 ohms ± 1%, 1/4 W.	H-1510-494
R6	Same as R5.	RESISTOR, film, 1.110K ± 1%, 1/4 W.	H-1510-495
R7	Crystal current shunt adj.	RESISTOR, variable comp; 5K ± 10%, 2 W.	HA-23318
R8	Gain control on front panel.	RESISTOR, variable comp; 10K ± 10%, 2 W.	HA-23316
R9	Crystal series resistor.	RESISTOR, comp; 1.5K ± 5%, ½ W.	H-1009-365
R10	Grid return for V2.	RESISTOR, comp; 56K ± 5%, ½ W.	H-1009-815
R11	Diode load.	RESISTOR, comp; 270K ± 5%, ½ W.	H-1009-866
R12	AGC limiting.	RESISTOR, comp; 2.2K ± 5%, ½ W.	H-1009-237
R13	Cathode bias for V2.	RESISTOR, comp; 68 ohms ± 5%, ½ W.	H-1009-243
R14	Damping resistor on L1.	RESISTOR, comp; 10K ± 5%, ½ W.	H-1009-416
R15	Part of plate load resistor for V1.	RESISTOR, comp; 390 ohms ± 5%, 1 W.	H-1009-323
R16	Decoupling.	RESISTOR, WW; 500 ohms ± 5%, 12 W.	H-1100-162
R17	Screen dropping for V2.	RESISTOR, comp; same as R1.	H-1009-348
R18	B + supply filter.	RESISTOR, WW: 1.1K ± 5%, 12 W.	H-1100-212

Table 6. Table of Replaceable Parts (Continued)

SYMBOL NO.	FUNCTION	DESCRIPTION	RFL PART NO.
R19	B + supply filter.	RESISTOR, WW: same as R18.	H-1100-212
R20	OHMMETER ZERO ADJUST on front panel.	RESISTOR, variable: comp; 1K ±10%, 2W.	HA-23315
R21	Meter dámpening.	RESISTOR, comp; 1.5K ±5%, ½W.	H-1009-365
R22	Voltmeter full-scale adjust.	RESISTOR, variable: comp; 1K ±10%, 2W.	HA-23311
R29	Voltage divider.	RESISTOR, film: 240K ±1%, 1/4W.	H-1510-498
R30	VOLTMETER ZERO ADJUST.	RESISTOR, variable: comp; 500K ohms ±10%, 2W.	HA-23310
R25	Ohmmeter voltage divider for R x 100 range.	RESISTOR, film; 800K ±1%, 1/4W.	H-1510-500
R26	Half-scale calibrate for R x 100 range.	RESISTOR, variable: comp; 250K ±10%, 2W.	HA-23312
R27	Ohmmeter voltage divider for R x 10 range.	RESISTOR, film; 750K ±1%, 1/4W.	H-1510-499
R28	Half-scale calibrate for R x 10 range.	RESISTOR, variable: comp; 25K ±10%, 2W.	HA-23313
R23	Ohmmeter voltage divider for R x 1 range.	RESISTOR, film; 511K ±1%, 1/4W.	H-1510-501
R24	Half-scale calibrate for R x 1 range.	RESISTOR, variable: comp; 500 ohms ±10%, 2W.	HA-23314
R31	Divider.	RESISTOR, film; 1.21 meg. ±1%, ½W.	H-1510-502
R32	Divider.	RESISTOR, film; 619K ±1%, 1/4W.	H-1510-503
R33	Divider.	RESISTOR, film; 162K ±1%, 1/4W.	H-1510-504
R34	Divider.	RESISTOR, film; 82.5K ±1%, 1/4W.	H-1510-505
R35	Divider.	RESISTOR, film; 46.4K ±1%, 1/4W.	H-1510-506
R36	Divider.	RESISTOR, film; 31.6K ±1%, 1/4W.	H-1510-507
R37	Divider.	RESISTOR, film; same as R31.	H-1510-502
R38	Divider.	RESISTOR, film; same as R32.	H-1510-503
R39	Divider.	RESISTOR, film; same as R33.	H-1510-504
R40	Divider.	RESISTOR, film; same as R34.	H-1510-505

Table 6. Table of Replaceable Parts (Continued)

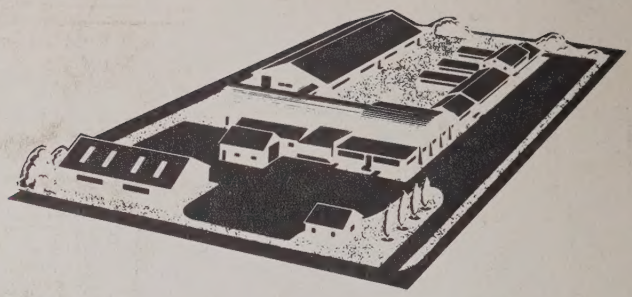
SYMBOL NO.	FUNCTION	DESCRIPTION	RFL PART NO.
R41	Divider.	RESISTOR, film; same as R35.	H-1510-506
R42	Divider.	RESISTOR, film; same as R36.	H-1510-507
R43	Divider.	RESISTOR, film; 1 meg. ±1%, 1/4 W.	H-1510-508
R44	Divider.	RESISTOR, film; same as R43.	H-1510-508
R45	Cathode bias.	RESISTOR, comp; 680 ohms ± 5%, ½ W.	H-1009-464
R46	Cathode bias.	RESISTOR, same as R45.	H-1009-464
R47	Meter zero.	RESISTOR, variable: comp; 1K ± 10%, 2 W.	HA-23321
R48	Series Res. for meter zero.	RESISTOR, comp; 470 ohms ± 5%, ½ W.	H-1009-458
R49	Decoupling	RESISTOR, WW: same as R3.	H-1100-159
R50	Shunt on gain control.	RESISTOR, comp; same as R10.	H-1009-815
R51	Divider.	RESISTOR, film: same as R29.	H-1510-501
R52	Fixed calibrating resistor.	RESISTOR, carbon film; 3K ± 1%, 1/8 W.	H-1510-175
R53	Fixed calibrating resistor.	RESISTOR, carbon film; 4K ± 1%, 1/8 W.	H-1510-176
R54	Fixed calibrating resistor.	RESISTOR, carbon film; 5K ± 1%, 1/8 W.	H-1510-177
R55	Fixed calibrating resistor.	RESISTOR, carbon film; 6K ± 1%, 1/8 W.	H-1510-178
R56	Fixed calibrating resistor.	RESISTOR, carbon film; 7K ± 1%, 1/8 W.	H-1510-179
R57	Fixed calibrating resistor.	RESISTOR, carbon film; 8K ± 1%, 1/8 W.	H-1510-180
R58	Fixed calibrating resistor.	RESISTOR, carbon film; 10K ± 1%, 1/8 W.	H-1510-181
R59	Fixed calibrating resistor.	RESISTOR, carbon film; 20K ± 1%, 1/8 W.	H-1510-182
R60	Fixed calibrating resistor.	RESISTOR, carbon film; 50K ± 1%, 1/8 W.	H-1510-183
R61	Fixed calibrating resistor.	RESISTOR, carbon film; 75K ± 1%, 1/8 W.	H-1510-184
R62	Fixed calibrating resistor.	RESISTOR, carbon film; 100K ± 1%, 1/8 W.	H-1510-185

Table 6. Table of Replaceable Parts (Continued)

SYMBOL NO.	FUNCTION	DESCRIPTION	RFL PART NO.
R63	Fixed calibrating resistor.	RESISTOR, carbon film; 125K ±1%, 1/8 W.	H-1510-186
R64	Fixed calibrating resistor.	RESISTOR, carbon film; 150K ±1%, 1/8 W.	F-1510-187
R65	Fixed calibrating resistor.	RESISTOR, carbon film; 200K ±1%, 1/8 W.	H-1510-188
R66	Variable calibrating resistor.	RESISTOR, variable: comp; 500K ±20%, ½ W.	HA-5521
R67	Variable calibrating resistor.	RESISTOR, variable: comp; 50K ±20%, ½ W.	HA-5522
R68	Variable calibrating resistor.	RESISTOR, variable: comp; 5K ±20%, ½ W.	HA-5523
S1	Crystal Term. Res. (ohms)	SWITCH, rotary: 3 pos., 1 pole.	HB-23319
S2	A-R switch on front panel.	SWITCH, rotary: 6 pos. 1 pole, one section. (R-A)	HB-16484
S3	FREQUENCY RANGE switch on front panel.	SWITCH, rotary: 7 pos., 5-pole, 5 sections, 30° index.	HB-17829
S4	SELECTOR switch on front panel.	SWITCH, rotary: Selector.	HB-5576
S5	OHMMETER socket shorting switch.	SWITCH, subminiature: single-pole, double throw.	HA-4843
S6	Volt changeover switch.	SWITCH, toggle: DPDT	HA-3710
S7	Volts Full Scale Crystal Term. Res.	SWITCH, rotary: 6 pos. 2-pole.	HA-23320
T1	Power Transformer	TRANSFORMER, power.	HC-5678
V1	Drive amplifier.	TUBE, electron: miniature beam power amplifier, 6005.	HA-5529
V2	Phase-inverting amplifier.	TUBE, electron: miniature RF amplifier penthode, 5749.	HA-5530
V3	Voltmeter.	TUBE, electron: miniature twin triode, 5751.	HA-4835
V4	B + supply rectifier.	TUBE, electron: full-wave, high vacuum rectifier, 5Y3WGT.	HA-5222
V5	Voltage regulator.	TUBE, electron: voltage regulator, OB2.	HA-3666
V6	Voltage regulator.	TUBE, electron: voltage regulator, OA2.	HA-3665

Table 6. Table of Replaceable Parts (Continued)

SYMBOL NO.	FUNCTION	DESCRIPTION	RFL PART NO.
V7	Voltmeter adjust.	TUBE, electron.	HA-5656
X1	To hold V1.	SOCKET, turret: 7-pin w/shield base.	HA-5573
X2	To hold V2.	SOCKET, turret: same as X1.	HA-5573
X3	To hold V3.	SOCKET, turret: 9-pin w/shield base.	HA-5574
X4	To hold V4.	SOCKET, tube: 8-contact.	HA-4787
X5	To hold V5.	SOCKET, tube: 7-contact.	HA-4789
X6	To hold V6.	SOCKET, tube: same as X5.	HA-4787
X7	CRYSTAL socket on front panel.	SOCKET, crystal: 2-contact.	HA-4558
X8	OHMMETER socket on front panel.	SOCKET, crystal: same as X7.	HA-4558
X9	To hold C10.	SOCKET, tube: same as X4.	HA-4787
X10	Connector for octal base crystal holders.	SOCKET, tube: 8 contacts.	HA-5572
X11	To hold C15.	SOCKET, tube: same as X4.	HA-4787
X12	To hold V7.	SOCKET, tube: same as X5.	HA-4789
		STRAIN RELIEF.	HA-7019



Warranty

The Model 541C 2.5-1100 kc Crystal Impedance Meter carries a warranty of 12 months from date of delivery for replacement of any part, except tubes, which fails during normal operation or service. A deficient part should be returned to the factory, shipping charges prepaid, for replacement f. o. b. Boonton, N. J.

RFL Industries, Inc.,
Boonton, New Jersey, U. S. A.

Manufacturers of

Magnetics Equipment

Meter Calibrators & Supplies

Crystal Impedance Meters

Voltage, Current & Temperature Measuring Instruments

RFL Industries, Inc.

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